Bachelor’s thesis

Professional Sales

Sales Management

2016

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SUPPLIER PERFORMANCE VARIATION MANAGEMENT

– Statistical Process Control

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BACHELOR'S THESIS | ABSTRACT

TURKU UNIVERSITY OF APPLIED SCIENCES

Professional Sales | Sales Management

2016 | 48 pages

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SUPPLIER PERFORMANCE VARIATION MANAGEMENT – STATISTICAL PROCESS CONTROL

The goal of this thesis is to find out how supplier performance variation management can be done and to test Statistical Process Control – SPC as a tool for variation management. The case company is Sandvik Mining and Construction Oy's Turku site. The main research problem is variation in supplier performance. It causes slowdown to Turku site's manufacturing and weakens both suppliers' and Turku site's own delivery accuracy. Weak delivery accuracy could cause business losses. Variation management could improve supply chain process and decrease warehouse costs, manufacturing costs, HR – human resources costs and indirect costs.

Supplier performance, variation management and SPC are covered from the viewpoint of purchasing department in theory part of this thesis. SPC tools: control charts and quality board are tested for purchasing and the process of testing explained in the case study. The purpose of control charts is to show the variation in supplier deliveries in statistic. Control charts are grouped in three categories: high, medium and low variation suppliers. The case presents that by continuously monitoring delivery accuracy variation the supply chain process could be improved. Quality board is used for measuring purchasing process and for finding its failures. That is done in the purpose of standardizing the purchasing process.

The objective of this thesis was accomplished. The result that control charts can be made for supplier delivery accuracy and used as variation management tool is covered in the conclusions part of this thesis. Control charts are concluded to be useful in buffering planning in variation management. Using quality board is concluded to need improving for future use. Main improvement in the use of quality board is to be used as a team project. Using SPC tools in variation management would need changes in Sandvik's current processes the management's support and willingness to make changes would be crucial.

KEYWORDS:

Variation, Variation management, Statistical Process Control (SPC), Supplier performance, Supply chain management, Purchasing

OPINNÄYTETYÖ (AMK) | TIIVISTELMÄ

TURUN AMMATTIKORKEAKOULU

Myyntityö | Myynnin johtaminen

2016 | 48 sivua

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TOIMITTAJIEN SUORITUSKYVYN VAIHTELUN HALLINTA – SPC-MENETELMÄÄ KÄYTTÄEN

Tämän opinnäytetyön tavoite on tutkia miten toimittajien suorituskyvyn vaihtelua voidaan hallita ja testata siihen tilastollista prosessin ohjausta – SPC:tä. Toimeksiantajana toimii Sandvik Mining and Construction Oy:n Turun toimipiste. Tutkimusongelma on toimittajien suorituskyvyn vaihtelu. Se aiheuttaa hidastumia Sandvikin Turun tehtaan tuotantoon ja heikentää toimittajien sekä Turun tehtaan toimitusvarmuuslukemia. Heikko toimitusvarmuus aiheuttaisi tappiota. Vaihtelun hallinta voisi parantaa toimitusketjuprosessia ja niin ollen vähentää kuluja varaston, tuotannon ja henkilöstön hallinnan osa-alueilla sekä epäsuoria kuluja.

Teoriaosuudessa käsitellään toimittajien suorituskykyä, vaihtelun hallintaa sekä SPC:tä oston näkökulmasta. SPC-työkaluja; ohjauskortteja ja laatutaulua, testataan ostotoimintaan. Testausprosessi on selostettu case-osuudessa. Ohjauskorttien tarkoitus on kuvantaa toimitusvarmuuden vaihtelu tilastollisesti. Ohjauskorttitulokset on jaettu kolmeen ryhmään toimittajien toimitusvarmuuden vaihtelun mukaan: suuren, keskisuuren ja matalan vaihtelun ryhmiin. Case-osuudesta ilmenee, että toimitusketjuprosessia voitaisiin parantaa jatkuvalla toimitusvarmuuden mittaamisella. Laatutaulua käytetään ostoprosessin mittaamiseen sekä sen vikatilojen tutkimiseen. Tarkoituksena on ostoprosessin standardisointi.

Opinnäytetyön tavoitteeseen päästiin. Johtopäätöksissä käsitellään tuloksia siitä että toimitusvarmuuden ohjauskortteja voidaan käyttää ja hyödyntää vaihtelun hallintaan. Ohjauskorttien käyttö nähdään hyvänä keinona puskureiden suunnitteluun vaihtelun hallinnassa. Jotta laatutaulua voitaisiin käyttää jatkossa parannusten nähdään olevan tarpeellisia. Laatutaulua tulisi käyttää tiimiprojektityökaluna. Tilastollisten työkalujen hyödyntäminen vaihtelun hallinnassa vaatisi muutoksia Sandvikin nykyisiin prosesseihin. Tämän takia johdon tuki sekä muutoshalu olisivat ensiarvoisen tärkeitä.

ASIASANAT:

Vaihtelu, vaihtelun hallinta, tilastollinen prosessin ohjaus, toimittajien suorituskyky, toimitusketjun hallinta, ostotoiminta

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LIST OF ABBREVIATIONS

ERP	Enterprise Resource Planning
HR	Human resources
LCL	Lower Control Limit
OTD	On time delivery. Means the same as delivery accuracy
SIPOC	Diagram used for defining a process (suppliers, inputs, process, outputs, customers)
SPC	Statistical Process Control
UCL	Upper Control Limit
8D	Eight Disciplines Problem Solving – a problem solving tool

1 INTRODUCTION

The largest employer in the Finnish technology industry is Mechanical Engineering and manufacturing. It is also the largest export industry in Finland. The industry includes a wide range of different products and their manufacturers. (Ammattinetti 2015) One of them is mining equipment industry. The competition is hard; companies need to develop their business continuously. One of the main priorities in the mining equipment is quality. Safety and quality are the most important factors of the machines so that the mining can be done safely and efficiently. For guaranteeing quality and for developing it the company needs to develop its operations in all fields.

In this thesis focus is on supply chain management, more specifically on supplier performance from the viewpoint of a manufacturing company's purchasing department. The theoretical viewpoint of this thesis is variation management as part of supply chain management. It includes finding the actions that a purchasing company should do when there is variation in supplier performance, planning and making the improvement continuous.

In the beginning of theory part supplier performance is defined. Then the terms variation management and Statistical Process Control (SPC) are explained and studied. In the case study the process of data collation is described and it is studied how SPC fits into purchasing. SPC control charts are tested as a tool for variation management with delivery time data. The aim is to test in which ways delivery time can be measured, how and when the SPC could be used in purchasing. The commission was given by Sandvik Mining and Construction Oy's Turku plant. The case study is concluded from the viewpoint of purchasing. In the conclusions part suggestions for future continuous variation management are made.

2 SUPPLIER PERFORMANCE

Supply chain of a product is a process which consists of several companies and their actions. Together they formulate a chain which outcome the product is. For the supply chain to start there needs to be demand. That is why demand-supply chain is more used definition. (Sakki 2015, 4- 5)

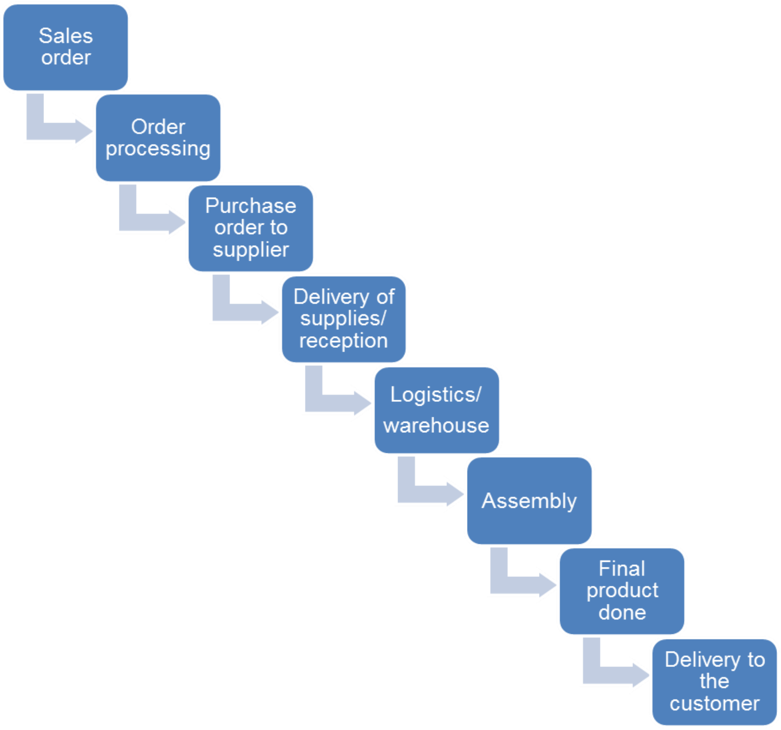


Figure 1. Demand-supply chain.

In the Figure 1 above I have illustrated the demand-supply chain basing on my own knowledge. The chain starts from demand – customer sends a sales order. The order goes to order processing where it is itemized which parts are needed for assembly the product. The needed items are then purchased from suppliers - they manufacture and deliver them. Ordering from suppliers is done basing on terms of contract. With new supplier invitations for tenders must be sent and contract negotiated before purchasing items. When the items are delivered reception and logistics distributes them to the right places to the stock and to the assembly. Final product is done in the assembly and finally delivered to the customer. In the modern definition of supply chain also materials, information, machines and people are included. Materials have four inventories through the supply chain: raw materials (parts which will be processed), work in process (WIP), finished goods inventory (FGI) and spare parts (used for maintenance and repair of machines). (Piirainen 2014a, 104; Iloranta and Pajunen-Muhonen 2015, 49)

Performance of a process is defined by measuring the process. (Karjalainen and Karjalainen 2002, 38) Supplier performance measures the delivery process of an item. In Attachment 1 I have listed what supplier performance consists of. All the factors can be measured. That is how supplier performance can be defined. As I am concentrating on delivery accuracy with this thesis I find measuring delivery times and purchasing process the most important factors. There is no one right way to measure these processes. The right tools can only be found by testing different statistical tools.

2.1 Supply chain management

Supply chain causes 50-80% of companies' total costs. For Finnish manufacturing industry direct purchases form little less than 60% of companies' turnover. When also investment purchases, service purchases and other indirect purchases are calculated to the amount, the percentage goes over 80. As supply chain plays a significant role in companies' costs, it is wise to have some kind of supply chain management. Supply chain management consists of several actions for suppliers, manufacturers, warehouses and customers which aim is to secure that right supplies are produced and distributed right amounts to right places at right time. Minimum costs in all phases and good service levels are leading principles in supply chain management. (Simchi-Levi, D., Kaminsky and Simchi-Levi E. 2004, 2; Iloranta and Pajunen-Muhonen 2008, 85; Myerson 2012, 6)

Reducing supply chain costs have a positive impact to the profit margin. Variation management can improve the supply chain process and that way reduce costs. Variation management is also important for preventing problems in the supply chain. If there is variation already in the beginning of supply chain it will be multiplied in the next phases of supply chain. The figure below demonstrates that effect. (Iloranta and Pajunen-Muhonen 2008, 85; Myerson 2012, 6)

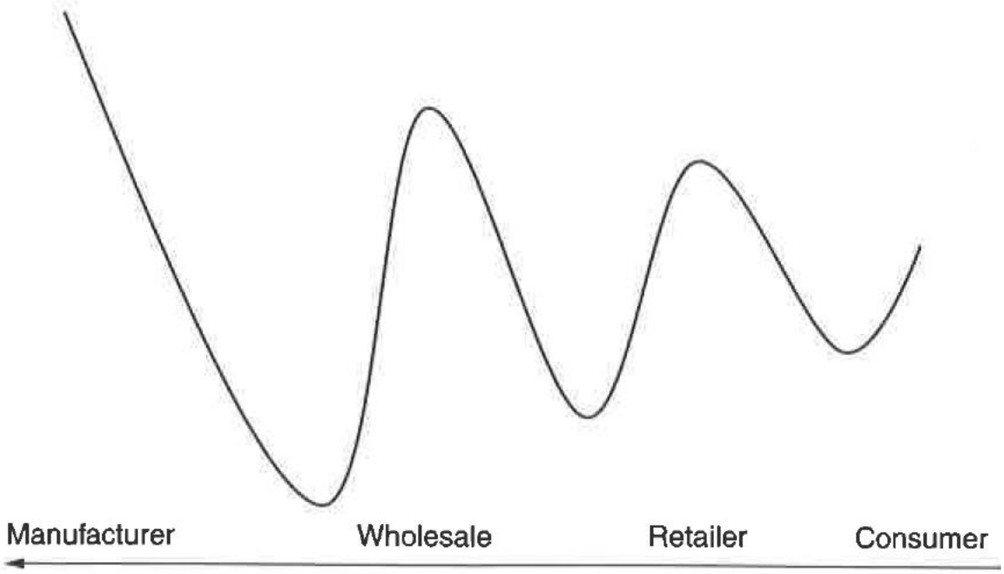


Figure 2. Bullwhip effect (Myerson 2012,6).

In the Figure 2 above the bullwhip effect is demonstrated using consumer product but the bullwhip effect happens in manufacturing industry also. When looking the figure from right to left it is seen that sudden variation in demand causes increasing variation to the previous phases of supply chain. For example if the purchased item is delivered sometimes early and sometimes late, purchasing will have to increase the use of buffers just to secure the stock balance. That means they will start to purchase some items earlier than needed and in larger quantities. So variation of delivery times causes variation in the purchasing process. (Iloranta and Pajunen-Muhonen 2008, 353; Myerson 2012, 6)

Also, if there are no demand forecasts to supplier, supplier needs to use orders as forecasts. In that case if purchasing orders large quantity of an item supplier will build a safety stock for that item assuming there is high demand for it. But if the next order is small quantity of the same item (order quantities varies) supplier's safety stock is useless. So the variation of demand has caused variation in order quantities and even bigger variation in supplier's production. Costs have increased in all phases. (Simchi-Levi, D., Kaminsky and Simchi-Levi E. 2004, 21; Iloranta and Pajunen-Muhonen 2008, 353; Myerson 2012, 6)

All the variation in the delivery process will cause variation in the lead time of the final product because assembly will have to wait some parts whereas some parts are delivered on time. When the lead time varies, also the final products delivery time vary and that has a negative impact on the customer satisfaction.

3 VARIATION MANAGEMENT

The first step in variation management is understanding variation. Variation means deviation in a process. It can be any reason that causes slowdown to the process. In the best situation, there is as little variation as possible or none. That means that everything goes as planned in the process and situations that may cause variation are prevented. Based on the law of variability, variation decreases the performance of a manufacturing process. (Piirainen 2014a, 9) That is why management of the variation is needed. When the variation is managed, it causes minimum problems to the manufacturing process and to the efficiency of the supply chain. Variation management is a qualitative way to increase productivity and efficiency. (Piirainen 2014a, 22.)

Variation can be divided into two types: common cause variation and special cause variation. There is common cause variation in every process. It can be any regular, normal reason that causes slowdown to the process. Common causes of variation can be for example variation of employees' skills, variation of working conditions; such as ergonomics and conditions, meetings during the day which cause a stop to other ongoing job or deficient instructions. Whatever the reason is, its lengthening impact on the process time can be noticed in the mean and in the standard deviation. (Ledolter and Burrill W. 1999, 308-309; Piirainen 2014a, 67, 143.)

Special cause variation means a sudden incident that causes slowdown to the process. Those incidents can be for example sudden sick leave of an employee or a machine breakdown. Special causes create the majority of unexplainable variation. That causes extra costs and poor quality. Those factors decrease productivity and lengthen the time that a job stands in hold before it goes to production. Because special causes are a key cause of variation, it is important to recognize the special causes and to control them. (Piirainen 2014a, 67, 143.)

SPC is often used when companies want to find ways of decreasing variation. It means measuring, identifying and improving both common causes and special causes of variation. Variation decreasing makes the whole process more efficient. In this thesis, decreasing variation is not the aim. Decreasing variation of supply performance would mean measuring and consistently improving all the factors listed on Figure 2. It would require actions from suppliers. The purpose of variation management is to find ways of controlling the process as it is by solving the special causes, not so much the common causes. (Piirainen 2014a, 12, 27.)

There are three different buffers which can be used for the variation management: adding stock, adding time and adding capacity. Wallace J. Hopp and Mark L. Spearman call variation management the law of variation buffering in their book Factory Physics (1996). Their main reason for doing the variation buffering is that productivity and competitiveness of a process can be increased by variation management. If there is no variation management, all the buffers go higher. That increases costs in all areas: warehouse costs, capacity costs and manufacturing costs. So the buffers are good tools for variation management but their use needs to be planned sensibly. (Piirainen 2014a, 12, 27.)

3.1 Demand forecast

In order to have a fluently operating production and supply chain, demand must be forecasted. Company needs to have internal forecasts so that all operations can plan and schedule their needed actions for the final product. Final products production must be forecasted: when the production starts and ends for which final product. Schedules must be set so that there is taken into account all the lead times for all the components that are needed for the final product. (Hugos 2011, 42, 43.)

In external forecasts to suppliers needs to be defined which items are needed, what amounts and when are the needs. Forecasts need to be as accurate as possible. There are several problems if demand for the parts differs from forecast; more items than forecasted to be needed can be difficult to get because supplier has been prepared for smaller amount of needed items. Also if demand suddenly drops less than forecasted, supplier can demand the buyer to purchase anyway all the items listed in the forecast. (Hugos 2011, 42, 43.)

3.2 Stock buffer

Securing that demand of an item does not go over the quantity of the items on stock, companies can use safety stock. In that way manufacturing always have parts to use and does not have to wait for them even when demand is suddenly greater than anticipated in forecasts or when delivery is being delayed. The minus factors are that a safety stock increases stock value and stock lead time. It also slows down stock turnover. There cannot be safety stock for each item or the costs would be lot bigger than benefits. That is why it is good to measure the variation of different suppliers' performance and build safety stock for only those items which it is necessary. (Sakki 2003, 87; Hugos 2011, 13.)

Safety stock can also be outsourced to supplier's responsibility. Vendor management inventory (VMI) means that supplier maintains the safety stock to items agreed with buyer. There is normally contract where the safety stock items are listed and determination of liability is stated. (Iloranta and Pajunen-Muhonen 2008, 49.)

3.3 Delivery time buffer

Delivery time starts from the moment when supplier receives an order and ends to the moment when the order is delivered to customers' reception. Ideal delivery date would be the exact date when the item is needed. That is seldom the situation. There needs to be couple of days extra just for logistics; to get the items received, taken to right places on stock and from the stock to correct station in the assembly. Also transportation can take sometimes more time than requested. Forecasts are again important here; delivery is the shorter the earlier the demand has been informed to the supplier. (Sakki 2003, 150, 151.)

Delivery time buffer means all the extra days calculated to the delivery time. When using delivery time buffer it needs to be remembered that all extra days on the stock increases the stock value. Also short notice deliveries become impossible if suppliers are used to have very long delivery times. With long-term partner suppliers delivery times are usually very accurate and reliable. Delivery time buffer is more used with new suppliers which way of working is yet unknown or with long delivery time items where all the process times are so long that it is normal that there is delays at least in some process phases. Customer needs to be prepared for those delays and common way of preventing that the delivery comes too late is to order it earlier than what the actual delivery time would demand. (Sakki 2003, 150, 151; Piirainen 2014a, 130)

3.4 Capacity buffer

When thinking about the whole supply chain capacity means the ability and efficiency to make and store products. In production process adding capacity quickly is usually done by adding shifts/working hours and outsourcing. Long-term capacity increasing would mean improving the current process and investing on new equipment/personnel. How those actions could be used in purchasing process? Adding capacity would mean purchaser working longer days for catching up with the demand variation. That is a fast but not cost-effective solution. It increases costs by overtime payment and decreases purchaser's coping with work. (Hugos 2011, 10-11; Vorne 2016)

Outsourcing would either mean delegating some of purchasers work load for colleague or outsourcing order to an alternative supplier. When the first choice supplier cannot respond to urgent demand alternative supplier can be used. Alternative supplier may be more expensive but is able to deliver on short notice. Improving current capacity can be done with qualitative improvement such as SPC etc. or improving by adding automation. For example certain supplies can be purchased automatically from the ERP without purchaser.

Qualitative improvement projects take time and effort but when done well the outcome is worth it. Investing new equipment can be new IT solutions and equipment and personnel investing means hiring more purchasers. (Hugos 2011, 10-11; Vorne 2016)

Factories with great capacity are able to react quickly to demand changes and other changes but keeping great capacity costs a lot. Capacity with no use decreases efficiency of process. Instead, factories where all capacity is in use are efficient and cause no extra costs of idle capacity but they are incapable to handle sudden demand variation. (Hugos 2011, 10-11)

4 STATISTICAL PROCESS CONTROL

Statistical process control means controlling process variability with statistics. Performance can be calculated by computer programs. There needs to be data to calculate. Data needs to have sigma (statistical word for variation). Sigma can be used in two different cases: to measure span (statistical word for deviation) and to be the measurement unit of span. Sigma is an average deviation from the mean. The smaller the sigma is the better is the performance – meaning the same as the smaller the variation in a process is the better the performance of the process is. In that case sigma measures the span. (Ledolter and Burrill W. 1999, 304; Karjalainen and Karjalainen 2002, 39)

In performance indicator sigma is compared to expectations. In that case the bigger the sigma figure is the better. Then it is a unit of measurement. So control of process variability – or variation management as I call it in this thesis includes both the controlling of process mean deviations as well as process variation changes. Statistical process control tools demonstrates the process current state, shows variation and unusual deviations and so helps us identify if process outcome is affected by special causes. By using SPC tools process can be stabilized which is the base of qualitative improvement. (Ledolter and Burrill W. 1999, 304; Karjalainen and Karjalainen 2002, 39)

4.1 Control charts

Control charts are basic tools of SPC. With control charts performance of a process can be calculated with indicators. Control charts are graphical charts which are used to monitor, control and stabilize the performance of a process. There are many kinds of control charts and when defining the process it is important to select a control chart that is suitable for measuring that process. That is done by monitoring variation and examining what are the reasons behind the variation, why and how the variation develops. Control charts indicate the performance of a process. It shows if the process is stable and controlled or not. Control charts also sort out common causes from special causes. With control charts special cause variation can be noted. There comes an out of control-signal when special cause variation occurs. (Karjalainen and Karjalainen 2002,170)

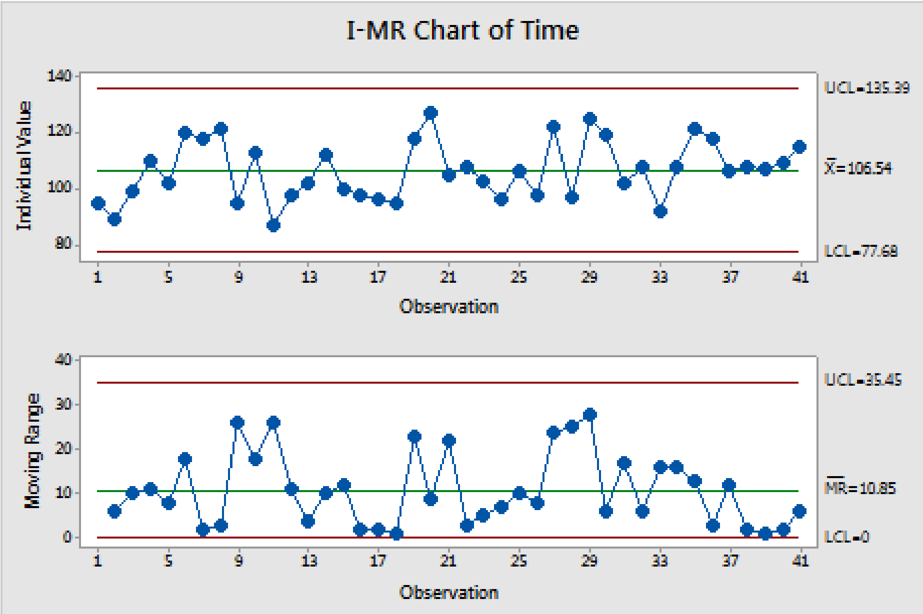


Figure 3. I-MR Chart (Minitab Support 2016).

In the Figure 3 above is an example of an I-MR chart. I am using I-MR charts with my thesis. The upper chart, Individual Value, is showing the variation of the mean of certain data. The lower chart is showing the moving range. The data points are the collected data which are being combined as a graph. UCL means upper control limit and LCL lower control limit. If the graph goes over the UCL or under the LCL immediate actions are needed. After those actions the real reason that caused the variation needs to be found out. Mean is marked with the green middle line. (Minitab Support 2016)

Control limits are calculated with 3 sigma. That was first created by Walter A. Shewhart in 1924 who also was the first to divide variation into two types: later named as common cause and special cause variation. The natural moving range of a process, the area between control limits, is calculated with a certain equation. So control limits are not based on theory of probability. 3 sigma limits are proven to show if the process includes stabile or non-stabile variation. (Piirainen 2014a, 43, 56, 57)

4.2 Quality boards

Quality board is a tool which can be used to find special causes in a process. It's a visual way to gather information of errors in the process and an effective tool for quality improvement together with control charts. One of the purposes of using a quality board is to standardize a process. It is a tool for a team; responsible persons need to be pointed out before starting to use a quality board. (Karjalainen and Karjalainen 2000, 15, 16) Below in the Figure 4 is an example of a quality board.

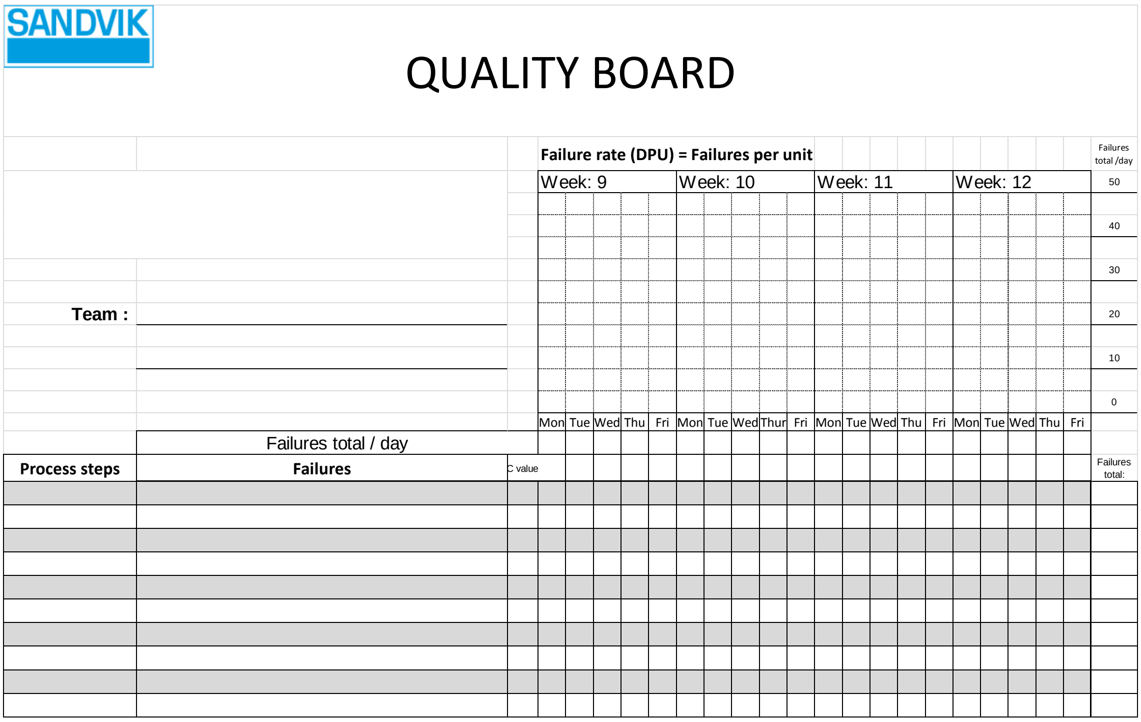


Figure 4. Quality board (Sandvik internal source 2016).

Process needs to be defined first and then the failures listed to each step of the process. Every time there is a failure in the process it needs to be mark down. For every failure C value is then calculated. That can be done by calculating it oneself or with Minitab. C value is the same as UCL in control charts. So a control chart, C chart, can be made of quality board results. (Piirainen 2014b, 223)

Total amount of failures for each process step can be seen from the quality board and needed controlling actions can be planned. When there is a failure, a special cause, immediate controlling actions need to be done. Those actions are done by the chosen people for that task. (Piirainen 2014b, 186, 188, 189)

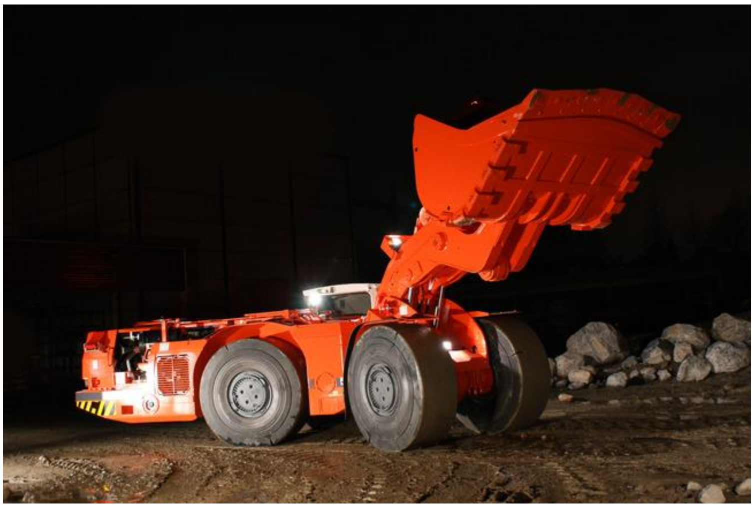
After immediate fixing controlling and preventing actions need to be figured out. The actions which need to be done are:

- Defining the special cause
- Analyzing how the failure happened (using a problem solving tool such as 5 Whys)
- Deciding what the preventing actions are
- Planning the actions
- Making it happen
- Valuating the done actions

All these actions are methods of finding the root cause of the variation. (Piirainen 2014b, 188, 189)

5 CASE: SANDVIK MINING AND CONSTRUCTION OY

Sandvik is a global high-tech engineering group which is organized into five business areas: Sandvik Machining Solutions, Sandvik Mining, Sandvik Materials Technology, Sandvik Construction and Sandvik Venture. (Sandvik and Solberg 2014, 4, 6) Sandvik was founded in Sweden in 1862. The head quarter is in Stockholm and in 2014 Sandvik Group had approximately 47 000 employees. In 2014 total sales was approximately 89 billion SEK. (Sandvik Group 2015) Sandvik's core values are customer focus, innovation, fair play and passion to win. The vision is “We set the industry standard”. It implements the strategy of being growth oriented, flexible and agile, truly global, technology leader and employing exceptional people. (Sandvik Group 2015)



Picture 1. One of Sandvik Turku's loaders (Sandvik internal source 2016).

Sandvik Group's subsidiary company operating in Finland is Sandvik Mining and Construction Oy. Sandvik Mining and Construction Oy is a leading global supplier for equipment, tools, service and technical solutions for the mining and construction industries. (Sandvik and Solberg 2014, 6) The company produces rock tools, drilling products, excavation products, crushing and screening machinery and bulk materials handling systems. (Sandvik Mining and Construction 2015)

Picture 2. One of Sandvik Turku's trucks (Sandvik internal source 2016).

In Finland, Sandvik is operating in Turku, Tampere, Lahti, Hollola and Vantaa. Turku plant produces underground loaders and trucks. There are about 450 people working in Turku plant. (Sandvik intranet 2015)

5.1 Defining the purchasing process

See separate attachment.

5.2 Choosing suppliers

See separate attachment.

5.3 Using the quality boards

See separate attachment.

6 DATA COLLATION: DELIVERY TIME CONTROL CHARTS

See separate attachment.

6.1 High variation suppliers

See separate attachment.

6.1.1 Supplier 1 (Supplier name changed)

See separate attachment.

6.1.2 Supplier 2 (Supplier name changed)

See separate attachment.

6.1.3 Supplier 3 (Supplier name changed)

See separate attachment.

6.2 Medium variation suppliers

See separate attachment.

6.2.1 Supplier 4 (Supplier name changed)

See separate attachment.

6.2.2 Supplier 5 (Supplier name changed)

See separate attachment.

6.3 Low variation suppliers

See separate attachment.

6.3.1 Supplier 6 (Supplier name changed)

See separate attachment.

6.3.2 Supplier 7 (Supplier name changed)

See separate attachment.

7 VARIATION MANAGEMENT: CONCLUSIONS

As a conclusion of researching variation management with SPC I would say that control charts are working well as delivery accuracy variation management tool. With this research I find it possible to stabilize the delivery process with control charts. From the chart it can be seen what is common cause variation and what is special cause variation. Control limits help finding and concentrating on the real issues – special cause variation, instead of trying to fix every single deviation in the process. Control limits could be helpful in planning buffers; buffer stock, delivery time buffer and capacity buffer. Planning could be done by following which items cause deviations and focusing on buffering for those items.

I found it useful to categorize the suppliers on three groups based on the delivery accuracy variation: high, medium and low variation suppliers. Categorizing would help purchaser to find the suppliers which process needs immediate controlling actions. Purchaser can for example categorize oneself his/her suppliers by comparing the variation results. That could also be done by using ABC analysis which categorizes suppliers based on their value and stock turnover of the items. Another way of categorizing the suppliers would be to compare all suppliers' variation results and then group them to the three categories. In that case it would need to be done together with team.

Variation management could be both purchasers' and sourcing people's responsibility because the immediate action – using buffer/buffers requires actions from both of them. In Sandvik sourcing and purchasing are two separate departments. Adding delivery time is done in the ERP system by purchaser but the new delivery time needs to be negotiated with supplier and sourcing responsible also. (Information deleted from the public version) purchaser and supplier can't decide to increase delivery time without sourcing's approval. Adding safety stock to supplier's warehouse should be agreed on the contract which is sourcing's duty. If the safety stock is in Sandvik's warehouse it should be negotiated with logistics department. Adding capacity could be decided with purchaser, sourcing and supplier. If adding capacity would require changes in purchasing team it is purchasing manager's duty.

For high variation suppliers problem solving tools such as 8D or root cause analysis could be used. Those tools are meant for deep inspection of the process. Basing on the result of the problem solving, correct buffer could be chosen. For high variation suppliers it is highly probable that there are causes of variation in supplier's process. Because of that, it is very important to check that purchasing process is working efficiently and correctly so that doesn't increase the variation further. One thing that was uniting high variation suppliers' purchasers was purchasers' work load. That I found out by interviewing purchasers and from quality board results. It is possible that there may be more variation with those suppliers whose purchasers don't have the time to confirm the orders oneself or correct the delivery dates.

For medium variation suppliers more conversation and information sharing between purchasing/sourcing and supplier would be recommended. Visiting the supplier is also one solution; that way buyer gets to know supplier's capacity, people and machines. To know what the suppliers are capable of, what is their core business field and what are their main interests help in making decisions between different suppliers and in choosing the correct buffer as a variation management tool. The more buyer and supplier know of each other's processes the better the co-operation is.

With low variation suppliers the co-operation is likely going well already so keeping the business relationship good is important. To share the information of how the good relationship is built and maintained can help with high or medium variation suppliers also. Especially with similar type of suppliers who deliver similar items it would be good to compare the relationships – what is going well with the other and what could be learned from the other. Open dialogical connection makes it easier to control the process and prevent possible problems if changes that are coming are informed beforehand.

Delivery accuracy control charts are possible to code to ERP (information deleted from the public version). The code would come from Excel. The coding should be planned by IT professionals. If the charts would be visual they should be monitored on daily basis by purchaser to be able to see the current variation and do immediate controlling actions if there is UCL or LCL crossing deviations. The charts could be then checked for example monthly by purchaser and sourcing person together. They would see which suppliers are having high variation on delivery accuracy and focus on those. Suppliers who deliver many rows every week the variation checking should be done weekly at first in order to define the items which cause the variation repeatedly and for which items buffers should be used. That could lead to increasing the use of buffers. In order to keep the balance and not buffering all items it is also important to check that there are no unnecessary buffers for low variation suppliers' items.

Using the control charts the 3 sigma control limits would need to be accepted to use. (Information deleted from the public version) The idea of control charts is to concentrate the variation management actions, buffering, to those deliveries which caused special cause variation. (Information deleted from the public version)

I didn't find quality boards a good variation management tool with this thesis. The main problem was that quality board is designed to be gathered and used as a team. It didn't work well that I made it mostly by myself. It led to that all the colleagues didn't agree with the content of the board or the purpose of it. How it could be used in the future is to make it as a team. Firstly the goal of using the quality board would need to be discussed and determined together; why it is being used and how. Controlling the use of quality board should be on the project's team leader's responsibility so that the project is the team leader's main work task. Management's support would be crucial in this.

I found it difficult to do my own purchaser job at the same time as this thesis and also having to control the colleagues using the quality board. In several quality philosophies such as Six Sigma and Lean it is emphasized that team work and focusing on the project is crucial. Most qualitative tools are meant for project group to use and not for individual person. If results are wanted it would need to be secured that there is enough resource to do a project, choose a project team and manage it so that there isn't too large work load for anyone.

Normally standardizing a process is a goal for using a quality board. If that is wanted to do for purchasing process it should be first checked that purchasers purchasing processes are comparable. Now the situation was that work load were so uneven that it wasn't possible to compare the results. ERP should be used in the same way and not everyone differently; order confirmations should be checked by the purchaser her/himself, amount of projects and other responsibilities beside the ordering process should be checked. My quality board results with this thesis could be useful with that. There can be seen results of the same problems repeating with same purchaser as well as some more common problems that repeat with several purchasers.

I would sum up that management's support and willingness to make changes would be the most important factor in making the variation management with SPC possible. Finding the variation – using control charts, making the variation management with SPC continuous by starting to plan the buffering with control charts and controlling the purchasing process with quality board all require changing the current processes. As I researched: supply chain causes nowadays 50-80 % of companies' total costs so I find improving supply chain important. Supplier performance variation management would be one way to improve the supply chain process.

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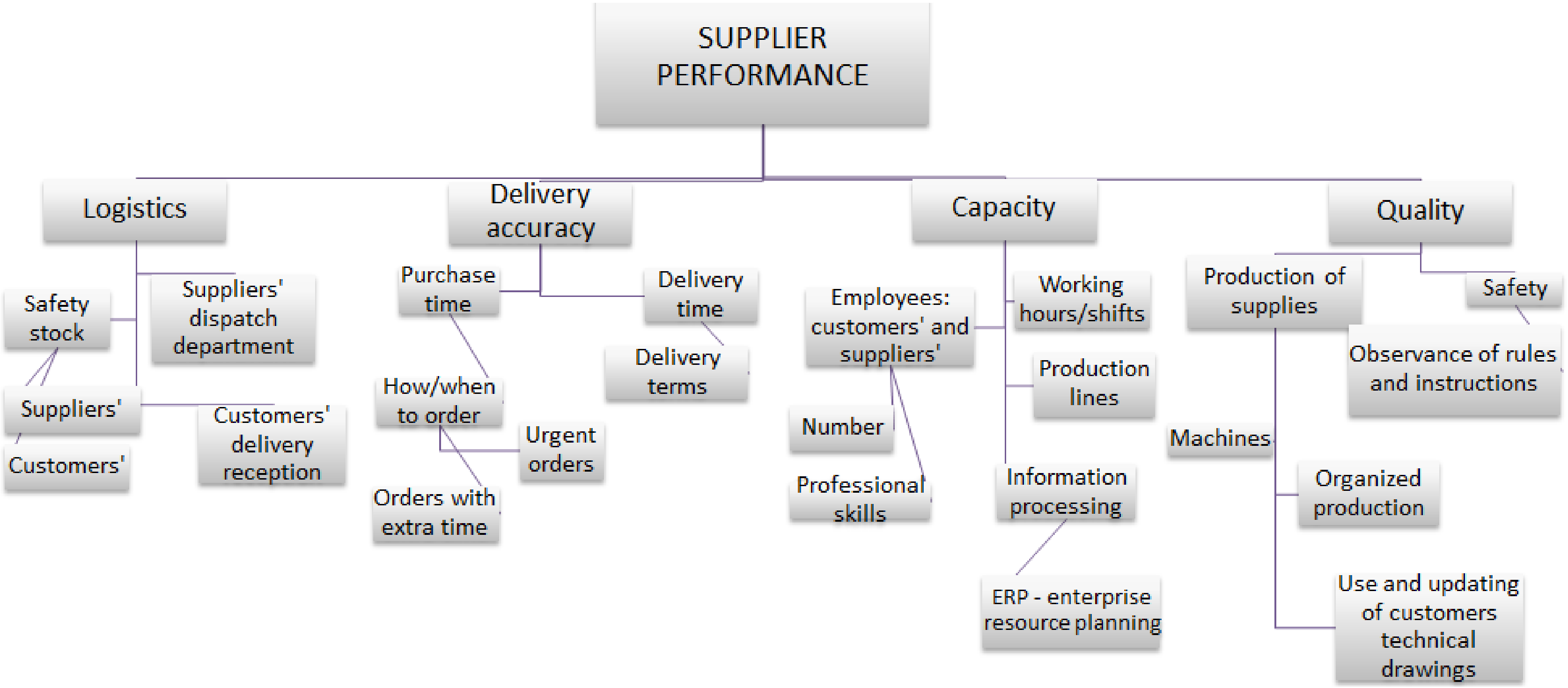
Appendix 1. Supplier performance chart



Appendix 2. SIPOC

(Information deleted from the public version)

Appendix 3. Process description

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Appendix 4. Quality board results

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